Advanced Communications Engineering

- Founded in late 1990, a Delaware stock corporation
- Three founders, controlling 95% of the voting stock
  - Donald K. Dement, President
  - G. Gordon Apple, Vice President, Engineering
  - Scott Finer, Vice President, Finance
- Located in the National Capital Area
- Currently refining business plan and seeking capital

Integrated Services Digital Broadcast
ISDB

A Proprietary Broadcast Operating System
integrated with a
Digital Cable or Satellite, Receiver/ Decoder

for the

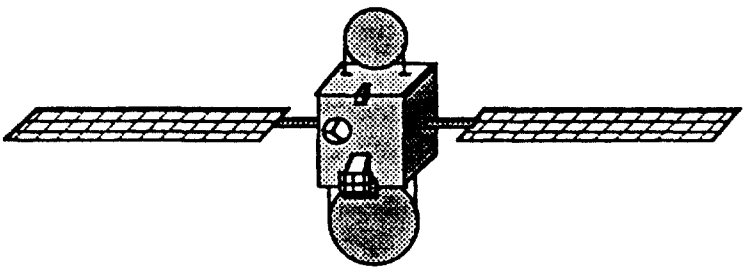
Consumer Electronics Market

Presented to

Don Rodebaugh and Tim Haggerty

July 10, 1992

Advanced Communications Engineering



Submitted: October 13, 1989
Start Date: March 1, 1990 Duration: until March 1, 1993

An Integrated-Services Digital DBS* Receiver

(* Direct Broadcast Satellite)

A Proposal Submitted in Response to NRA-89-055A-14
National Aeronautics and Space Administration
Satellite Communications Application Research Program
by:

Foundation for Educational Advancement Today
(a nonprofit educational organization)
2419 Ocean Avenue, Venice, CA 90291
Advanced Communications Engineering, Inc.
Advanced Communications Corporation

Amount Requested of NASA: $1,350,044 (over three years)

Principal Investigator: Dr. G. Gordon Apple (213-540-6532)

Business Personnel:
Gary S. Coe (213-821-5902); Daniel H. Garner (501-377-1493)

Executive Summary

DBS (Direct Broadcast Satellite) space technology has matured, and new, efficient, high-power satellites are now under construction which will allow service reception with antennas as small as 60 cm or less in diameter as shown in Figure S-1. But, a major question facing the DBS community is a decision concerning analog vs. digital transmission. This is not a simple choice of equivalent technologies. The difference for transmission is as important as that between the analog and digital computers of years past, and between analog vinyl records and digital compact disks (the latter making possible CD ROM and related capabilities). A mistake on this issue will relegate the United States to a secondary position in satellite broadcasting. A correct decision—utilizing digital transmission—will open vast new applications of space communication technology for both public and private user services.

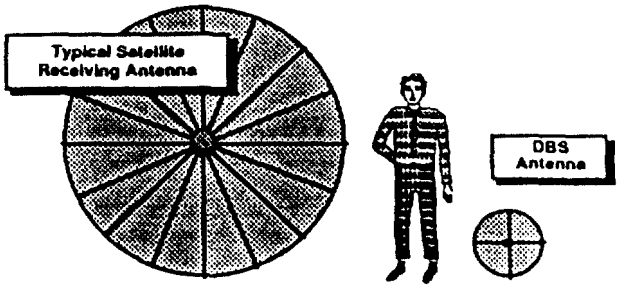


Figure S-1 DBS Antenna Size Comparison

The primary remaining need is for inexpensive digital receivers. The RF section, using two-foot dish antennas and low-noise converters, will be the same for analog or digital transmission. For any services now under consideration, inexpensive digital demodulation, error correction decoding, and service selection capabilities are required. A receiver for this important area of the near future of satellite communications does not currently exist.

The primary objective of the proposed program is to show feasibility of digital DBS transmission by doing the system design, developing a digital transmission breadboard and a prototype digital receiver, and sizing the required LSI (large-scale integration). This will be accomplished by leveraging existing designs based on work that we have already completed. An additional objective is to develop a computer-based service demonstration which can show some of the types of services (and simulate others) that could not be offered by analog transmission means (see Figure S-2). The anticipated result of

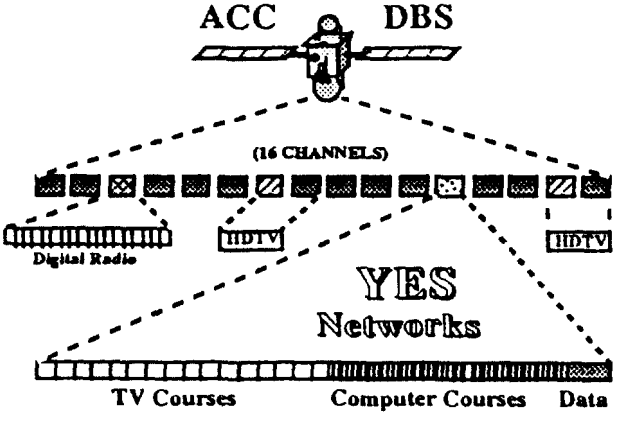


Figure S-2 Integrated Digital DBS Services

the proposed program is that digital DBS transmission will be proven feasible, thereby demolishing a potential barrier which could prevent the implementation of such a versatile and worthwhile medium.

Although the proposed studies, development, and demonstration are ultimately intended for the competitive marketplace, there are immense social benefits to the public—particularly in the area of education—from the use of digital broadcasting. The team that will participate in this program is uniquely qualified to realize the ultimate benefits of carrying forward the initial work. The purpose of the Foundation for Educational Advancement Today (FEAT) is to assist in funding the YES (Your Educational Services) Networks, an innovative education broadcasting system. Toward this goal, Advanced Communications Corporation (ACC) is donating the use of two DBS transponders for their useful lives. Without digital DBS transmission, the YES Networks could never come into being. Therefore, FEAT has a vested interest in the successful development of digital transmission through DBS satellites.

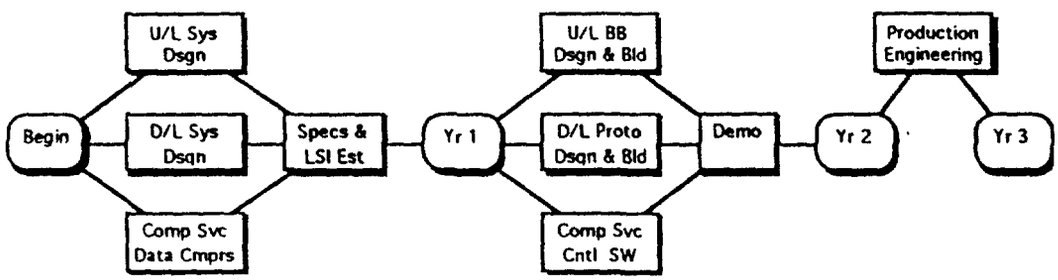


Figure S-3 Basic Components of the Proposed Program

The major components of the proposed program are shown in Figure S-3. The three year program consists of system studies, designs, and specifications during the first year, and the development of an uplink breadboard and downlink prototype and demonstration of computer related services during the second year. Manufacturing design for transition to production will constitute the third year, the detailed planning of which will be accomplished during the first year.

Considering the stated goals of the SCAR program, we believe that there could not be a more pertinent effort to the future of commercial space communications. We therefore suggest that it be given full consideration and funding.

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1.0 Introduction and Background

1.1 Digital Satellite Broadcasting

The advantages of digital transmission are well known to the space communications community. Indeed, deep space probes would have been virtually impossible without it. Digital transmission allows system design flexibility and a reliability of fidelity that cannot be attained otherwise. Telephone distance transmission and switching are rapidly becoming all digital and the digital local (ISDN) telephone loop is not far behind.

Digital recorded music has driven out analog LPs and (at least in studios) digital television recorders are taking over—digital home VCRs are only a matter of time. AM radio is being displaced by much higher fidelity stereo FM, even though many urban areas have saturated the limited number of FM channels and much of rural America does not have access to adequate FM or television reception.

A large number of proposals have been made to establish a transmission format for HDTV even though all of them require extensive digital processing (and degradation) to shoehorn the signal into a standard 6 MHz analog terrestrial TV channel. Television distribution to stations and cable headends is almost entirely by satellite today. However, until access control recently became an issue, transmission was totally by analog FM. Even with access control, the video is still analog. Similar transmissions are being used for televised distance learning in many classrooms. Meanwhile, many satellite transponders carry digital signals for telephone and data channels, and occasionally for digitally-compressed conference video.

NASA's pioneering efforts in the early 1970s, when the ATS-6 and CTS (Communications Technology Satellite—joint U.S./Canada) programs were developed, resulted in two major demonstrations that could profoundly influence our future:

- High EIRP, first produced by ATS-6 and followed by CTS, showed that broadcasting to inexpensive terminals could foster educational growth in areas unable to acquire it otherwise;
- Ku-band, first operated on the CTS system, opened the way for small user antennas.

These demonstration satellites accomplished much more—but the use of satellites for remote one-way communication to small terminals set a stage for the unequalled, inexpensive dissemination of wideband information.

That stage has been dark since 1976. While the industry grew to use much of the information from these programs, it has been slow to capitalize on the Government investment to illustrate uses of high EIRP. Video courses now are used broadly and the value of television for education is well established, but the receiving equipment has disappointing limitations. It must include a large antenna, and even so, yields only a fraction of the possibilities of satellite broadcasting. Small antennas and inexpensive receivers with fully digital capability could finally realize the promise of satellite transmission.

Direct Broadcast Satellites (DBS) originally were seen as a means of offering high-quality television directly to homes in areas without adequate service, and as an alternative to cable in other areas. Also, local prohibition of satellite receiving antennas, which is quite prevalent, has been preempted by the FCC for antennas less than 1 meter in diameter. Comsat mounted a high-power, three channel DBS project in the late 1970s but aimed it only at entertainment. Despite NASA's pioneering and the FCC's encouragement through new spectrum allocations, Comsat's attempt was among several startup programs in the industry that failed. However, in the subsequent years, technology to improve small earth terminals and enable larger satellites has brought a better economic match, and recently, wideband digital transmission also has matured.

High EIRP satellites with a few channels now are operating for other nations as they move into DBS for entertainment television. For the U.S., thirty-two channels at each of four locations that may cover CONUS with EIRPs in the 51-57 dBw range will mean that terminals can be bought and installed by homeowners without difficulties of location, unsightliness, or high-strength mounts, among others. Sixteen channels per satellite now are possible serving terminals as small as the 1975, one-channel CTS—60 centimeters—as opposed to the 2- to 4-meter antennas required for C-band TVRO today. Now that economics of building, launching, and operating sixteen channels are attractive, U.S. companies are in contract to build such satellites. Based on current schedules, U.S. DBS systems should be operating well within four years.

So far as is known, other DBS operators plan to broadcast analog television programming, similar to that from terrestrial and cable transmission media. But today's needs reach beyond entertainment, sports, news, and weather, although these still are highly valued. Introducing to the DBS transmission capability a digital format would bring all the flexibility of information-source manipulation and customization for a wide variety of purposes.

We are aware of the current enthusiasm and tension in the industry about establishing standards for HDTV. These standards activities are focused on signal format and display technology development more than on transmission. Their concerns about transmission have largely been dead-ended, because existing broadcast radio spectrum is closely guarded and cable systems would have major hardware investments to make in order to adapt to HDTV. Satellite transmission is known to be a potent solution, but until small user terminals are demonstrated with HDTV, little real enthusiasm will be displayed for this medium.

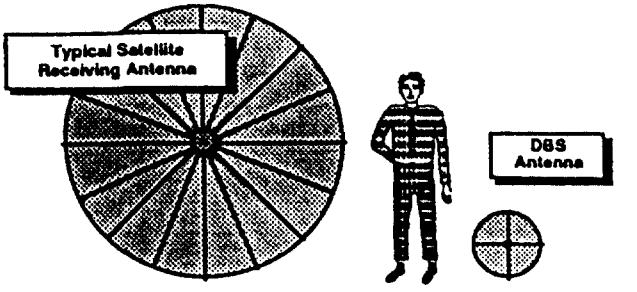

Figure 1-1 DBS Antenna Size Comparison

We are discussing with industry leaders and government agencies the considerable advantages of digital satellite transmission in general, and expecting that digital satellite transmission of compatible HDTV in particular will come to notice for serious consideration. For example, combining two 30 Mbps digital streams, one from each of two DBS transponders—one being NTSC compatible and the second being an augmentation channel—will almost certainly be more easily and cheaply accomplished than combining complex analog and partially-encoded digital streams, as some propose.

The opportunity to reach homes anywhere in America via DBS avoids the slow-growth syndrome otherwise likely with HDTV. The transmitter and/or cable plant costs will restrict it to being transmitted first only within cities, then slowly moving into suburbs, and perhaps never reaching rural areas.

As we now move toward an era of true Direct Broadcast Satellites (DBS), digital transmission has become economically feasible. **An unprecedented onetime opportunity is now present,** offering the advantages of digital broadcasting of a multitude of services to all of America. As we shall see, there is much more than television at stake.

The receiver proposed in this SCAR-sponsored development would show NASA's leadership in satellite transmission technology by enabling not only television transmission in any format, including HDTV, but a broad range of services only possible by digital transmission—while basing the development on its pioneering history, as noted above.

1.2 Integrated Services

Digital satellite broadcasting offers something basic that cannot be offered by any analog system—virtually unlimited flexibility and versatility of information flow—all from the same digital

spigot. For the first time, it will be possible to offer a completely integrated broadcast system which can offer:

- Superior versions of present-day audio and video services;
- New video services such as Extended Definition, High Definition, Three-D, interactive, and educational television;
- Wideband data and electronic publishing services;
- Emergency broadcast services;
- New types of broadcasting services using personal computers;
- Highly-efficient, innovative, educational course broadcasting systems, such as that of the "YES Networks".

Once the information is available in digital form, it is simply a matter of proper packaging (packetizing, addressing, and formatting), buffering, and prioritizing for timely delivery. Transmission-efficient mixes of services will allow a scale of economy never before achievable by other transmission means.

For example, a data-compressed television signal may require an average transmission bit-rate of less than half of the available instantaneous bit-rate, as long as it has top priority among other data for the full bit-rate when needed. Many other types of services, not having such stringent real-time requirements as television, could use the remaining transmission capacity.

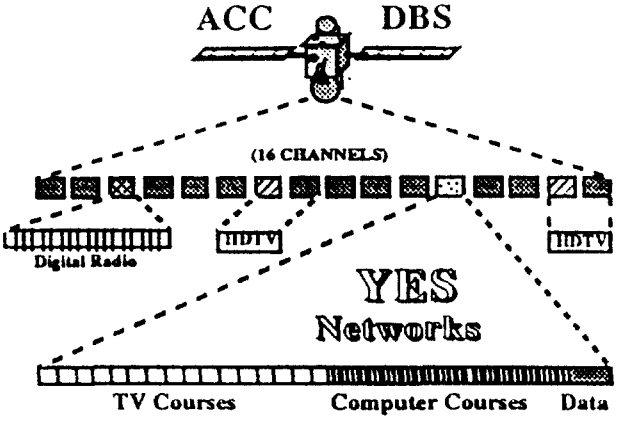

Figure 1-2 Integrated Digital DBS Services

Another area of flexibility is signal robustness. Even smaller receiving antennas could be used for emergency and other broadcast services by adding an additional layer of error correction coding or by repeated-symbol transmission to receivers capable of phase-coherent symbol combining. Packets of such robust information could easily be combined in the same basic data stream and format as other services.

The particular service mix would not need to be pre-allocated but would continue to evolve according to service needs. The digital satellite broadcasting system would not only have flexibility for today, but for the first time would provide a broadcast transmission format which could easily be updated to meet the unforeseen broadcast needs of the future, thus precluding obsolescence.

1.3 Rationale for the Proposed Work

A new era of information services will begin when digital satellite broadcasting becomes a reality. The described digital satellite broadcast system is not a distant fantasy. It can be implemented very soon, propelling the United States back into a position of leadership in commercial space applications. The use of digital transmission in satellite broadcasting also will have impact on the future of computer, television, and overall commercial electronics in the U.S. and its ability to compete in world markets.

The proposed development is particularly appropriate within the NASA goal of supporting U.S. global leadership, because it represents the initiation of improvements in direct-to-home services that no other country has begun. In 1977 at the Broadcast WARC, the U.S. led the Western Hemisphere away from World accord by rejecting the DBS parameters established on the then-current, practically obsolete, technology. At the conclusion of the 1983 Western Hemisphere's RARC, the U.S. had shown that technology would permit many more channels at less power, while using the orbit more efficiently.

Along with the multi-channel satellite technology of the last few years, NASA now can fulfill that expectation even more completely by supporting the U.S. in becoming the leader in digital DBS broadcasting. This could well be adopted by other nations, enabling an export business to arise in DBS earth stations that some predict will have a market size in the tens of billions of dollars.

The proposed development also is appropriate within NASA's mission as a technical consultant for spectrum utilization. It promotes the use of already-allocated DBS spectrum in lieu of rearranging, at great cost and disruption, the current terrestrial cable and broadcast allocations, while not requiring any changes to current (C- and Ku-band) satellite allocations or assignments.

Space commercialization is another supported area of NASA interest in this proposed development. Although DBS began in the '70s with NASA through expenditures of hundreds of millions of dollars, a true U.S. DBS industry is yet to be realized. Just recently, however, private industry has seen it as viable and is willing to proceed, albeit for some using only the simpler and less-effective analog television. Continuing DBS support by the same Programs Division at NASA would be a traditional outcome of its past ventures into new telecommunications technology, while simultaneously supporting NASA's newer commercialization mission.

A missing applied technology to bring these promising services to wide fruition is the user receiver. With DBS channel bandwidth of 24 MHz, the required constant-envelope modulation, power limits, and desired receiving antenna size, it appears that about 30 Mbps is a practical channel rate. The receiver must reliably match this stream to a variety of user needs, which must include

high-quality television. But integrating services with television for a variety of uses, including education, requires significant development.

The proposed program would provide the basic studies, system design, equipment prototypes, and demonstrations needed to prove technical and economic feasibility of digital transmission for a unified satellite broadcast system.

NASA's goals in providing for technological and economic preeminence in satellite communications, and to enable new and innovative services in support of private and public sector needs would be directly met by the proposed applied research work—moreover, by identifying and supporting methods to accelerate transferal of the results of this research to the user community.

1.4 Related Work

A significant amount of conceptual and preliminary system design work toward the stated goals already has been accomplished by the proposers:

- Detailed link budgets have been established for 30 Mbps digital transmission of television and other services from DBS satellites to 60-cm. receiving antennas;[1,2]
- System designs have been done for compression and decompression of standard television and HDTV (relevant to this program in terms of ultimate goals and transmission system design);[3]
- Conceptual designs and multiplexer traffic analysis tools have been developed for educational television and computer course broadcasting;[4]
- A preliminary design has been done for a digital demodulator (including carrier and symbol acquisition and tracking) which uses a proprietary algorithm and is intended for inexpensive LSI implementation;[5]
- Sophisticated modem simulation software has been developed for the Mac II computer;
- A floating-point DSP (Digital Signal Processor) co-processor board and associated software has been developed for the Mac II and can be used for high-speed simulation and for computer services image data compression and decompression;

In addition, a large volume of work on related technologies has been completed by the proposers and many others in a variety of locations over a period of many years. The proposers were involved in some of the earliest work on low-cost DBS receivers and television-type data compression (for Picturephone® at Bell Telephone Laboratories, NASA ARC, and Hughes under GSFC contracts). Some of these 1970s projects laid the groundwork for frame-differential coding techniques, variable-

block-length synchronization, statistical multiplexing of televised images, and a variety of other related topics.

Over the years, other companies, such as Compression Labs and Picturetel, have arisen to commercialize high-ratio data compression on television images for video conferencing systems. These systems serve a definite purpose, but are rather limited in their motion rendition capabilities and are far too expensive for use in the type of system proposed here.

More recently, the work by Murakami[6] and others shows that very acceptable entertainment-type television can be transmitted at bit rates from 15 to 30 Mbps. This system, whose design is now several years old, has been extensively tested subjectively over a satellite channel (by Intelsat)[7] to verify its performance acceptability.

Many television satellite distribution systems are beginning to use digital transmission at least in part to encode and encrypt the audio and control portion of the channel. For example, VideoCipher II[8], which is being used by a large number of distribution channels and is available for home reception (with a large receiving dish), digitizes and encrypts its audio. Systems also are in use for digital transmission of conferencing-video through satellite transponders, but these are prohibitively expensive for home and school use. DBS transmission systems in Europe all use a form of multiplex analog component (MAC) transmission which includes digitized audio and other data channels. However, these systems use much lower digital data rates than that proposed for a fully digital television encoding system, and use FM for transmission, rather than direct digital modulation.

In the area of computer-related services there is much activity to allow computers to generate imagery for presentation, animation, video overlays, and overall integration of video information. Economical storage media are also making large strides with the recent introduction of relatively inexpensive digital tapes and recordable compact disks. Players for such media are still relatively expensive, as is usually the case with a brand new technology. However, they are expected to follow the same or faster learning curve, and should be economically accessible by the general population before this program is completed.

There are also rapid advances being made in the area of control software for computer related services. The most advanced of these is the "HyperCard" software that is being given away with every Macintosh computer. Many extensions to this software are now available on the market for controlling all kinds of video equipment, CD players, laser disk players, VCRs, and almost anything else conceivable.

The areas of digital signal processing and LSI (large scale integration) have advanced to the point where integrated-circuit digital demodulators can be designed which will operate in a variety of environments and whose performance suffers very little degradation from the theoretical limit. The combination of all of these technologies shows unequivocally that the time has come for consideration of a digital direct broadcasting service into homes, schools, and other institutions. It is definitely the right technology at the right time.

2.0 Objectives

The major objective is to provide the means of implementing many new innovative and desperately needed services that **would not be possible without digital satellite broadcasting**. The goals of the proposed program are to:

- Establish the technical and economic feasibility of a totally flexible digital satellite transmission pipe which can be used to broadcast many new services (including HDTV) to a very large base of users in homes, schools, libraries, businesses, government, and other institutions;
- Build and test breadboard hardware for the digital portion of the uplink transmission and a prototype for the digital portion of the downlink reception;
- Demonstrate a new type of personal computer generated broadcasting service (with capability of simulating many other new services) through an actual satellite channel using the developed transmission breadboard and prototype.

There seldom arises a proposed program with more potential for meeting the stated goals of NASA's space communications program: to help maintain the United States technological and economic preeminence in satellite communications, and to enable new and innovative services in support of private and public sector needs. Most people in technology-intensive industries recognize that the United States is rapidly approaching a critical crossroad. We can let the rest of the world supply our critical electronic technologies, or we can regain leadership and use technology to not only benefit ourselves economically, but also enhance our quality of life.

Establishing a digital satellite broadcasting system would change the equation of the economics of satellite broadcasting. The United States' preeminence in this field would be assured and would stimulate a vast number of new innovative services for both the private and public sectors which would not be possible otherwise. The worldwide demand for additional satellite broadcast capacity,

computer-related products, and digital processing equipment would be very large. In all of these areas, the United States is still relatively strong and could dominate these world markets.

The proposed program could also stimulate further future designs for other types of broadcast satellites such as cellular spot beam coverage for DBS broadcast to local areas, using current ACTS on-board switching capabilities.

Much of the technical basis for this proposed program has already been mentioned in the previous section. It is presently planned that ACC's DBS satellites would transmit 30 Mbps within a 24 MHz transponder. After error correction and other overhead, approximately 25 MHz is available for image or other transmission. It has been well established that this rate is adequate for transmission of compressed standard (NTSC) television signals. The present indications are that still lower rates can be achieved.

When digital transmission was considered for DBS services in the early part of this decade (e.g., the TRW/CBS HDTV DBS study—done by a member of ACE), digital transmission was expensive. Today, the cost has dropped sharply and continues to plunge. In fact, virtually every HDTV transmission proposal that has been made includes the same level of complexity of digital processing needed for transmission via a digital DBS system. For this and other reasons, the present proposal includes proving the feasibility of digital satellite broadcasting. It also includes demonstration of a totally new type of computer-generated service which will serve as a prototype for a large number of other related services.

3.0 Technical Approach

The primary technical approach is to take the conceptual and other more specific work that has already been done, bring it to a well defined state to where reasonably accurate estimates can be made as to its technical and economic feasibility under an LSI approach, and then carry it to a detailed electrical design and prototype stage. The computer service development would also be carried to where it could be demonstrated, using the prototype equipment, through an actual satellite link.

3.1 System Design and Feasibility

The system design phase will involve determining the requirements for the uplink modulation error correction coding, multiplexing format and capabilities, and information packet structure. It also will include the means of controlling access to the services (encryption, key control, etc.). The downlink modem work would determine the requirements necessary for acquisition and tracking of

the digital signal in the presence of degradations such as frequency offsets, high noise, and instabilities of system conversion oscillators.

The design would be carried to the level of determining the number of multiplier and addition bits for each of the stage of the digital filters. A design presently exists for all of these functions. However it is known to have certain deficiencies, particularly in the area of symbol synchronization. A modem simulator program has also been developed for the Mac II which almost meets the needs of the design trade-off work for this study. However, it will require modification for the exact signal format and to allow high speed simulation tradeoff studies using a DSP (Digital Signal Processor) co-processor board.

3.2 Uplink Breadboard and Downlink Prototype

Following the completion of the above tasks, a breadboard will be designed and built for the uplink portion of the digital transmission system, including the multiplexing, error correction coding, and modulation. It will also contain the necessary "hooks" for inclusion of service encryption at a later date. Prototypes will be designed and built for the downlink signal demodulation, error correction decoding, and service selection, and will include the "hooks" for service decryption .

All of the design work will be done on Mac II computers, most likely using the Douglas software package for circuit design and simulation. The produced net-list will then be used to either hand-wire the breadboard and prototype modules or will be provided to NASA in order to use their facilities for generating wire-wrap boards. This design could also be ported to a Valid work-station later for LSI design. This is an area where we expect to have further discussions with NASA about cost-saving measures or enhanced benefits that could result from the use of NASA facilities.

3.3 Computer Related Services

The computer services work will be done on a pair of Mac IIs containing DSP boards which will be used for image compression at the transmitter and image decompression at the receiver. Only a minimal amount of control software will be developed for this system during the first year. However it will be enough to allow a demonstration through an actual satellite using existing modulation and demodulation equipment.

Control software for the computer services will be implemented, based on HyperCard on the Mac II, and will allow a variety of services to be demonstrated. When the uplink transmission breadboard and downlink reception hardware have been completed, the computer-based services will be demonstrated through an actual satellite channel to a remote location. In addition, the video output at the remote location will also be converted to standard NTSC video for viewing on monitors or standard television sets.

4.0 Technical Plan

4.1 Tasks

The proposed tasks and their dependency relationships are shown in Figure 4-1. The first year consists mainly of the system studies, designs and tradeoffs of system components, demod simulations, computer image compression, a satellite demo using existing digital transmission equipment, and estimating costs of LSI receiver components for extracting digital signals. The second year consists mainly of breadboarding the digital transmission circuitry, building a prototype of the digital portion of a receiver, providing a first-level of control software for computer generated services, and a stand-alone demonstration through an actual satellite link using only the necessary external RF equipment. A third year for production engineering transition is planned and details will be worked out at the beginning of our first year project.

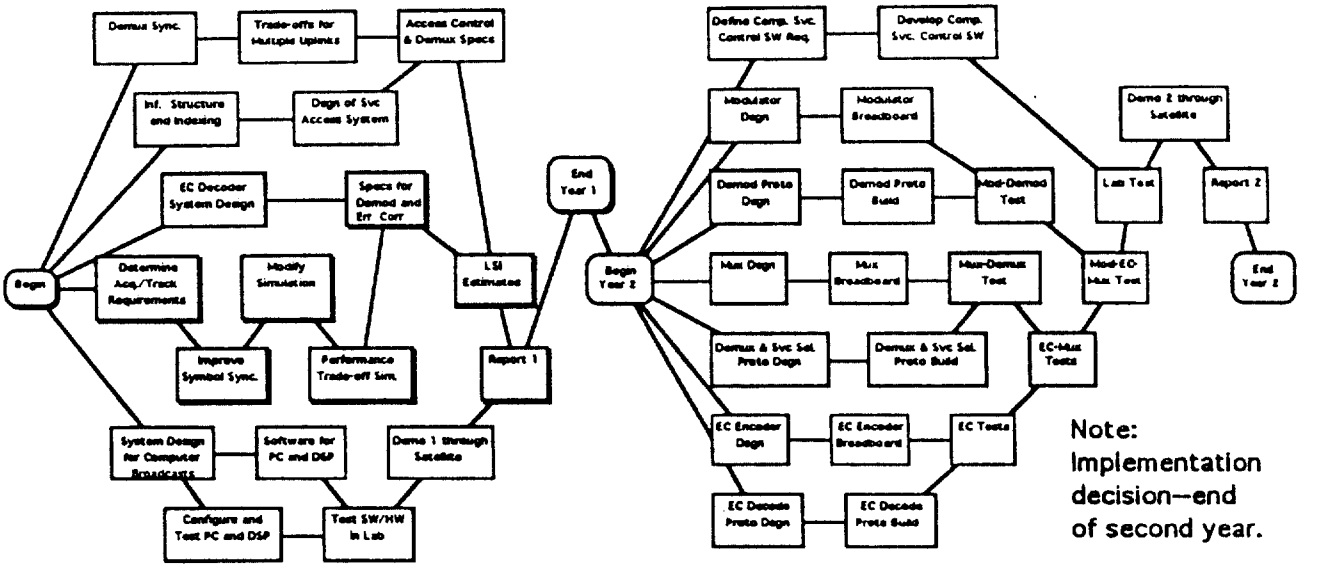

Figure 4-1 Tasks and Dependency Relationships

The decision to implement the described system would come after successful demonstration of the prototype through an actual satellite transponder toward the end of the program's second year.

First year tasks:

• Determine method to be used for primary message synchronization (should be robust enough for low G/T users); • Determine secondary message sync technique (packet or group of packets) and tradeoff methods of achieving for multiple uplinks; • Establish information-packet internal structure and method of locating data for a particular service (e.g., by header or by index list);

• Design service access system (encryption/decryption and crypto key management); • Establish and document specs (and hardware complexity estimates) for demux and receiver access control (for use in LSI estimates); • Determine system design for error correction decoder; • Establish acquisition and tracking requirements for receiver carrier and symbol sync (determined mostly by instabilities in other parts of the system such as conversion oscillators, Doppler, etc.); • Modify a symbol sync design (from a previous ACE design); • Modify existing modem simulator software to include OQPSK, include transponder effects, and run software objects on DSP (Digital Signal Processor); • Do design performance tradeoffs using modem simulator; • Establish and document specs for demod and error correction (for use in LSI estimates); • Determine estimates for LSI implementation in receiver (cost, power, number of chips, etc.); • Do system design for computer generated broadcasts (for educational and other services); • Design software for computer image compression-decompression and serial transmission (personal computer with DSP board); • Configure and test personal computer with DSP hardware; • Test image compression-decompression and serial transmission between computers; • Arrange for a demonstration of computer generated services through an actual satellite transponder using an existing modulator and demodulator; • Document first year's accomplishments.

Second year tasks:

• Define requirements for controlling computer service; • Develop computer service control software; • Design modulator breadboard; • Build modulator breadboard; • Design demodulator prototype (including carrier and symbol sync); • Build demodulator prototype; • Test demodulator and modulator together; • Design multiplexer breadboard; • Build multiplexer breadboard; • Design demultiplexer and service selection prototype (including decryption); • Build demultiplexer and service selection prototype; • Test demultiplexer and multiplexer together; • Design error correction encoder breadboard; • Build error correction encoder breadboard; • Design error correction decoder prototype; • Build error correction decoder prototype; • Test error correction decoder and encoder together; • Test error correction and multiplexing systems together; • Test error correction, multiplexing, and modulation systems together; • Test computer generated services with digital transmission system in lab; • Arrange for a demonstration of computer generated services through an actual satellite transponder using breadboard digital transmission and prototype digital reception equipment; • Document system and accomplishments in final report.

4.2 Schedule

The detailed time-line schedules for the first and second year's tasks are included in Appendix B along with the details of the manpower loading.

5.0 Anticipated Results and Implementation Plan

5.1 Anticipated results

The immediate results of this project should be the assurance that a 30 Mbps digital stream can be transmitted, received, demodulated, synchronized, error-corrected, decoded, and utilized in baseband processors coupled with computers and television sets without significant difficulty, at carrier-to-noise ratios typical of U.S. DBS systems being implemented; and that computer-generated services over such a digital link can be usefully realized.

In the larger view, this program will show that digital satellite transmission is a feasible means of disseminating a large number of services to the greatest possible number of users. It will show that a digital DBS transmission pipe can be made economically available for delivery of standard television, HDTV, educational course broadcasting, electronic publications, data services transmission, and a vast number of other innovative services. In establishing the viability of fully digital satellite broadcasting, it is expected that new, uniquely American approaches will develop for the next generation of television systems and other electronic service systems.

The development of digital satellite broadcasting will have immense potential for further commercialization of space, including the implementation of many more DBS satellites and new types of broadcast satellite services such as spot beam DBS, which would allow local-area coverage. By developing this technology, the United States will be able to develop new export markets—both in space and on the ground. Some other nations have already locked in their satellite broadcasts to analog transmission. The late entry of the United States into DBS services will allow the United States to leapfrog these countries by going directly into all-digital services.

5.2 Implementation Plan

The advent of digital broadcasting satellites will allow the development of totally new services and completely new industries that do not even exist today. Electronic publications and digital delivery of these publications will revolutionize the dissemination of information as we know it. Customized HyperMedia publications can be delivered in a form which can be conveniently viewed on what is rapidly developing into what we call the "Eltron," a conceptual drawing of which is shown in Figure 5-1. The Eltron is to be a lightweight portable device, about the size of a magazine, which will be capable of displaying both text and graphics and can be accessed in a HyperText-HyperMedia format. The educational implications of such a device, combined with digital transmission from the YES Networks (for real-time and off-line viewing), are staggering.

By the use of infrared or RF links to the main home or office computer, a virtually unlimited data and information base can be made available through the digital satellite broadcast. There are many other innovative services that will surely develop out of this technology, not the least of which will be interesting innovative educational techniques for science and mathematics education, which are so desperately needed.

In view of the immense potential of the digital DBS system for delivery of innovative educational services that would not otherwise be possible, ACC has agreed to provide two DBS transponders to the Foundation (FEAT) for use by the YES Networks for educational broadcasting. In addition, the Foundation has agreed to raise the funds to place a free DBS antenna in each of the America's public and private schools and assist in funding of the YES Networks (subject to showing feasibility of digital DBS educational broadcasting). The combined value of this effort is potentially several hundred million dollars.

As noted, this development program will be the start of a wideband digital receiver business. By the end of this development period, the associated company, ACC, will be well along in its satellite manufacturing and launch program. The coupling of the applied research results to the earth terminal manufacturing business will be guided by the DBS industry's foresight at that time. We believe that ACC will be leading the way in new services, and there may be others who, having already expressed interest in HDTV DBS broadcasting, may adopt these results and assist in the emergence of the receiver industry. There will be approximately one year before launch to initiate the commercial manufacturers into this wideband digital capability and to integrate into LSI the production engineering capabilities using technologies and techniques that will be sought and refined in this project. It is anticipated that, prior to this time, there will be receiver development interests in the industry that allow parallel work and an earlier start on production technology (see Figure 5-2).

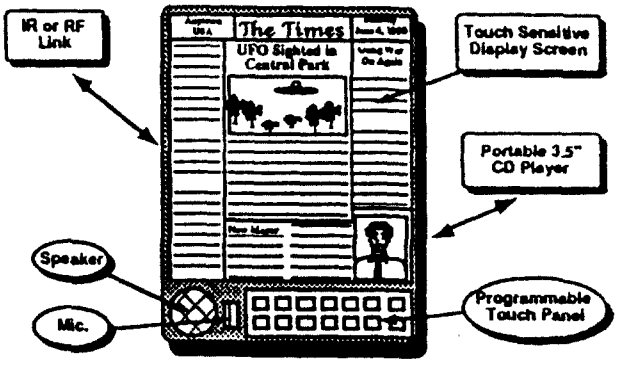

Figure 5-1 The "Eltron"

That is entirely possible, because there already exists an infrastructure. In the early '80s when the DBS prospects arose, a small terminal industry was begun specifically to serve the new high-power satellites. As DBS implementation delays set in, that body of knowledge that had, for the first time, generated small terminals with remarkable antenna efficiencies of over 75% turned to the "VSAT" market in the nearby low-power K_u-band. That industry has continued its progress, so that the understanding of small-terminal production for relatively narrowband, two-way digital satellite communications is in hand. The satellites serving these terminals are restricted in power and are closely spaced, putting a lower limit on the size of the terminal. This industry is now much more experienced and could readily absorb the technology from this SCAR project to its own and others' benefit.

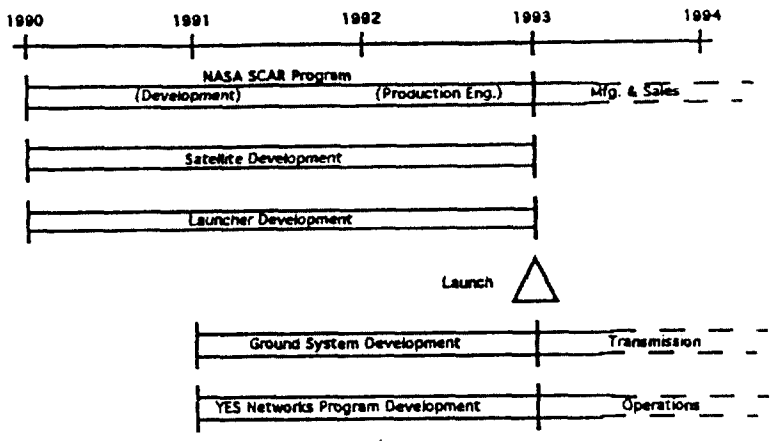

Figure 5-2 Implementation Schedule

Once significant progress is made, we plan a transition into production by establishing proper industry liaisons. In the case where the expected progress of DBS systems is not realized, the knowledge gained through this development should stand well in any of the dissemination technologies needed for the '90s, and we would then seek arrangements by which the appropriate design and production would be accomplished.

The longer-term outcome of this proposed development includes the earliest provision of well-known as well as new, beneficial telecommunication services directly to the American public. The social benefits of a better-educated population needs no explanation here, and such improvements are known to benefit everyone economically in the long run. The U.S. space community-at-large will have the opportunity to utilize the receiver technology in all DBS systems, and perhaps to apply the technology to other transmission systems.

The developments here will be the seed work for a new industry—one we believe has the enormous proportions recently given to the potential for HDTV. Sales of any kind of DBS receivers will likely be in the tens of millions, considering: (1) that even today several million Americans have no television access at all; (2) that the DBS user equipment will cost no more than a good-quality television set. Even for those who do have television access, the extraordinary attractiveness of the

wide range of services possible by digital transmission will far exceed the use, even in the future, of the fully analog terrestrial television channels.

6.0 Management Plan

6.1 Relationships of Teamed Organizations

The team members are: FEAT, ACC, and ACE.

ACC (Advanced Communications Corporation), one of two FCC authorized DBS permittees having 27-32 channels with desirable orbital locations. ACC will provide to FEAT two full-CONUS transponders for their useful life (anticipated to be twelve to fourteen years) for use by the YES Networks for educational broadcasting. ACC has advocated for several years the benefits of digital transmission to the FCC.

FEAT (Foundation for Educational Advancement Today), which has agreed to place a free DBS antenna in each of America's public and private schools and assist in funding of the YES Networks (subject to showing feasibility of digital DBS educational broadcasting), will coordinate and administer the activities of the project including receipt and disbursement of the funds.

ACE (Advanced Communications Engineering, Inc.), which has been the principal instigator of this digital DBS broadcasting concept, will be the main performer on this program when awarded.

6.2 Staffing

Complete vitae for the following people are included in Appendix A:

- The administrator and coordinator on behalf of FEAT will be Mr. Gary S. Coe;
- The technical project team leader will be Dr. G. Gordon Apple who will also perform many of the required system engineering tasks;
- Additional project direction and system engineering will be provided by Mr. Donald K. Dement.

The additional staffing required for the project is as follows:

- Digital Design Engineer—Will be involved in the initial system engineering studies, particularly in the sizing and LSI specifications; Primarily responsible for converting system designs and digital performance specifications into circuit designs and breadboard and prototype hardware;

- Software Engineer—Will be a Communications (Electrical) Engineer and will be involved with requirements definition, algorithm development, simulation, and control software on the Mac IIci, DSP-32C and control processors. Development will be done primarily in the "C" programming language (including in-line assembly code) on both the Mac IIci and DSP-32C. "HyperTalk" programming will be also be required for the HyperCard control software on the Mac IIci;
- Programmer—Will be required to program in "C", assembly, and "HyperTalk," and will do code generation to meet requirements established by the Systems Engineers and the Software Engineer;
- Electronic Technician—Construction and testing of digital electronic communications breadboards and prototypes. Must also be able to work with the Mac IIci personal computer;
- Secretary—Macintosh word processing, page layout documentation, technical typing, office coordination.

6.3 Facilities and Equipment

The facilities for this project's first year involve offices and a small electronics laboratory with personal computer facilities. The office would require approximately 1200 sq. ft. of combined floor space, located in the south-bay area of the Los Angeles basin. Design, documentation, project coordination and management, simulation, and collaborative efforts will be all done on Macintosh computers—mostly Mac IIci, plus two Mac SEs—interconnected by local network, modems, and Connect, Inc.'s "MacNet."

The second year requires the first year's facilities plus an augmentation of leased laboratory equipment, purchase of digital circuit components, and access to a satellite transponder, preferably at Ku-band. We intend to acquire this through arrangements previously made, or with commercial companies that could include both U.S. domestic operators with an interest in small-terminal digital transmission or international system operators. The third year will largely involve know-how and design transfer to a selected manufacturer.

6.4 Requirements for NASA Facilities and Expertise

No specific requirements have been identified for the use of NASA facilities at this time. However, we will explore the possibilities of using NASA facilities to aid in prototyping hardware, initial LSI sizing and design, and also for doing further television data compression algorithm refinements—the latter of which is a related need that is beyond the scope of the present proposal.

6.5 Schedule of Key Milestones

Figure 6-1 provides a summary view of the project planning charts, showing the major program components and key milestones. In addition, a third year should be considered for production engineering tasks leading toward full scale manufacturing of digital DBS receiver terminals.

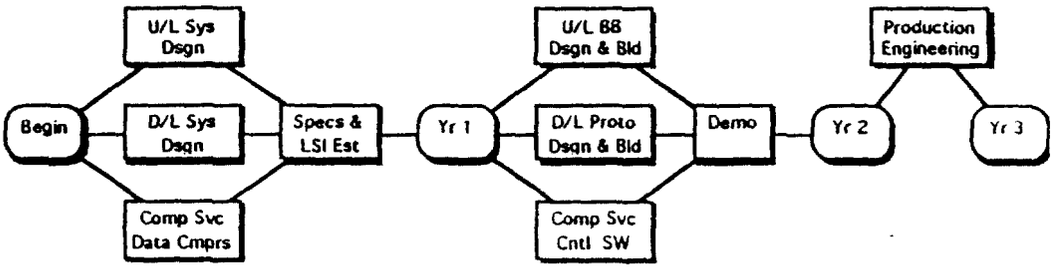

Figure 6-1 Key Milestones of the Proposed Program

7.0 Cost Plan

A summary of the total proposed program cost is shown in Figure 7-1. The details of the particular components are described separately.

Table 7-1 Program Budget

		First Year	Second Year	Third Year
Direct Labor		$252,250	$243,500	$121,000
Overhead	60%	$151,350	$146,100	$72,600
Equipment		$15,000	$20,000	$10,000
Materials		$17,000	$33,000	$5,000
Travel		$8,000	$8,000	$10,000
Fringe Benefits	15%	$37,838	$36,525	$18,150
Other Costs		$12,000	$5,000	$5,000
Subtotal		$493,438	$492,125	$241,750
G&A	10%	$49,344	$49,213	$24,175
Total		$542,781	$541,338	$265,925
3 yr. Total				$1,350,044

7.1 Direct Labor

The detailed direct labor rates, man-day durations, and costs are itemized in Appendix B by task and labor category and are summarized above. The combined project management and system engineering tasks (approximately one man-year during each year) is allocated at approximately 70% of Dr. Apple's time and approximately 30% of Mr. Dement's time. Mr. Gary S. Coe will support the administration tasks at a level af approximately 50%. The other technical employees (itemized in paragraph 6.2 and Appendix B) are allocated at approximately 100%. Other highly qualified individuals with skills applicable to this effort will be utilized at a 100% level.

7.2 Overhead

The overhead rate of 60% was determined from the values shown in Figure 7-2. One full-time secretary is allocated on overhead. The entire program depends on close communications and a commonality of development and documentation. Therefore each participant is allocated a leased Macintosh computer and a modem or net node. In addition the Digital Design Engineer is allocated a large-screen work-station monitor.